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For: A METHOD AND AN ELECTRICAL DEVICE FOR EFFICIENT MULTIRATE  
PSEUDO RANDOM NOISE (PN) SEQUENCE GENERATION

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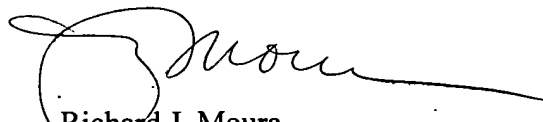
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Dear Sir:

CLAIM OF PRIORITY UNDER 35 U.S.C. § 119

Under the provisions of 35 U.S.C. 119 Applicant hereby claims the priority of European patent  
application no. 99610079.8 filed on December 22, 1999, which is mentioned in the declaration of the  
above-identified application. A certified copy of the priority document is filed herewith.

Respectfully submitted,



Richard J. Moura  
Reg. No. 34,883

Jenkins & Gilchrist, P.C.  
1445 Ross Avenue, Suite 3200  
Dallas, Texas 75202-2799  
214/855-4709 (Direct)  
214/855-4300 (Fax)

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**Attestation**

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

**Patentanmeldung Nr.    Patent application No.    Demande de brevet n°**

99610079.8

Der Präsident des Europäischen Patentamts;  
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets  
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**Blatt 2 der Bescheinigung  
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**A method and an electrical device for efficient multi-rate pseudo random noise (PN) sequence generation**

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A method and an electrical device for efficient multi-rate pseudo random noise (PN) sequence generation.

5 The present invention relates to an electrical device for generating a multi-rate PN sequence comprising:

- sequence generation means adapted to output a plurality of sequence values on the basis of a step control signal ( $S_t$ ).

10

The present invention also relates to a method of generating a multi-rate PN sequence comprising the step of:

- generating a plurality of sequence values on the basis of a step control signal ( $S_t$ ).

15

Pseudo random noise sequences (PN sequences) are used in many cryptographic and communications applications to provide randomly appearing symbols. Typically, cryptographic applications are methods to provide confidentiality of transmitted information through the use of stream ciphers. In communications systems PN sequences may e.g. be used as spreading sequences in spread-spectrum communications systems where they determine the hop sequence and/or the direct spreading sequence.

20

25

In general a receiver of a spread-spectrum communications system will receive a digital signal/bit stream transmitted over a single carrier frequency which is combined from a digital signal/bit stream containing information such as a digitized voice and from a PN sequence used to code or encrypt the transmission. Typically, the length of the PN sequence stream is much larger than the length of the information stream thereby,

30

35

complicating identification of ciphers containing the actual information.

5 In the prior art, the PN sequences are sometimes derived by using a maximal length polynomial. Constructions, whether hardware or software implemented, which form PN sequences, in this manner are sometimes referred to as m-sequence generators. It is well known that the randomness properties of the sequences generated by the m-sequence  
10 generators are very limited as a result of a linear relationship between the symbols of the sequence. This enables prediction of the next symbol given sufficiently many but small number of previous symbols. This is not desirable in various applications, and hence there is a  
15 need for efficient techniques to enhance the unpredictability.

Clock control of the m-sequence generator is a well-known method that can be used to increase the unpredictability  
20 of m-sequence generators. The most frequent method of clock control is that of introducing two modes of operation in an m-sequence generator. In one mode the generator outputs the previously produced symbol, and in the other mode the generator outputs the next symbol from  
25 the m-sequence. The current mode can advantageously be determined by another PN sequence. Output bits generated by a clock controlled m-sequence generator form the PN sequences which are used, inter alia, to encrypt or spread an information signal.

30 The abovementioned method of clock control, also sometimes referred to as the stop-and-go method, is especially used in hardware realisations where it is easy to implement this stop-and-go method. However, the  
35 randomness properties of the resulting sequence, although less predictable, are impaired by the fact that the



output sequence contains repetitions of previous symbols. This may be obviated by using a step-once or step-twice ( (1,2)-step) scheme, i.e. a basic m-sequence generator generates the next symbol (mode 1) or the symbol after  
5 the next symbol (mode 2), instead of the stop-and-go scheme. When implementing such a clock controlled generator, the basic m-sequence generator is required to produce symbols at twice the rate of the rate needed for output symbols. Known solutions for this depend on the  
10 use of a higher internal clock rate for the basic m-sequence generator or on the use of a very complex hardware realisation of clock controlled basic m-sequence generators.

15 EP 0905611 A2 discloses a pseudorandom number generating method and pseudorandom number generator where a selector selects a pseudorandom number  $X_j$  (a single bit) from either one of two function generator outputs on the basis of a previous pseudorandom number  $X_{j-1}$ . The two function  
20 generators output data composed of a plurality of bits corresponding to state data held in a register.

Another selector selects one of the data outputs of the function generators on the basis of the previous  
25 pseudorandom number  $X_{j-1}$  and stores this in the register as state data.

The abovementioned pseudorandom generator in EP 0905611 A2 does not disclose a clock controlled multi-rate  
30 generator and is subject to the abovementioned deterioration of unpredictability, since a clock rate twice as high as the needed output rate is needed because only one symbol is output at a time.

35 US 5,878,075 discloses a method of and an apparatus for generating a pseudorandom noise sequence (PN sequence),

where a bit sequence of pseudorandom numbers is augmented by a extra bit in order to comply with the Interim Standard IS-95 for implementation of CDMA (Code Division Multiple Access), where a sequence of  $2^{15}$  bits is  
5 required.

An object of the invention is to provide an electrical device for efficient multi-rate PN sequence generation of simplified construction which is capable of generating  
10 one or more m-sequences at a multi-rate.

This object is achieved by an electrical device of the aforementioned type, said the device further comprising:  
• selection means adapted to select one of said plurality  
15 of sequence values on the basis of a select value ( $M_t$ ),  
and  
• step control means adapted to provide the step control signal ( $S_t$ ).

20 Hereby, a flexible, efficient and cryptographically more secure generation of sequences of pseudorandom ciphers is provided, which avoids the use of multiple system clocks and only requires little additional hardware and thereby little additional power consumption.

25 In accordance with one embodiment of the device according to the invention, the select value ( $M_t$ ) is provided on the basis of a clock control value/signal ( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

30 In accordance with another embodiment, the step control signal ( $S_t$ ) is provided on the basis of a clock control value/signal ( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

35

In a preferred embodiment, the plurality of sequence values is two, the step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + M_{t-1}) \text{ DIV } 2$  and the select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } 2$ .

5

Hereby a (1,2)-step clock controlled m-sequence generator is provided with very little additional hardware.

Alternatively, the plurality of sequence values is four and the select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } 4$  and the step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + S_t) \text{ DIV } 4$ .

Hereby an efficient (1,2,3,4)-step clock controlled m-sequence generator is provided.

In general any N-step clock controlled m-sequence generator may be provided according to this invention, where  $N \geq 2$ . Accordingly the select value ( $M_t$ ) may be calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } N$  and the step control signal ( $S_t$ ) may be calculated as  $S_t = (C_t + S_t) \text{ DIV } N$ .

Hereby an efficient N-step clock controlled m-sequence generation method is provided which an unpredictability that grows with N.

In an embodiment the sequence generation means is a windmill polynomial sequence generator.

In yet another embodiment the sequence generation means comprises:

- a plurality of delay elements,
- step control means receiving a next block control signal as input, and
- sum elements,

where each delay element is connected to another and two of them are additionally connected to themselves via a sum element.

- 5 Hereby, a very simple and efficient implementation of a windmill polynomial sequence generator is provided.

Another object of the invention is to provide a method of efficient multi-rate PN sequence generation of  
10 simplified complexity which is capable of generating one or more m-sequences at a multi-rate.

This object is achieved by a method of the aforementioned type, said method further comprising the steps of:

- 15 • providing a select value ( $M_t$ ),  
• providing the step control signal ( $S_t$ ), and  
selecting one of said plurality of sequence values on the basis of the select value ( $M_t$ ).
- 20 In this way a method is provided which efficiently provides a PN sequence with enhanced unpredictability but with a small additional computational effort.

In accordance with one embodiment of the method according  
25 to the invention, the select value ( $M_t$ ) is provided on the basis of a clock control value/signal ( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

In accordance with another embodiment, the step control  
30 signal ( $S_t$ ) is provided on the basis of a clock control value/signal ( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

In a preferred embodiment, the plurality of sequence  
35 values is two, the step control signal ( $S_t$ ) is calculated

as  $S_t = (C_t + M_{t-1}) \text{ DIV } 2$  and the select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } 2$ .

Hereby a (1,2)-step clock controlled m-sequence  
5 generation method is provided with very little additional computational effort.

Alternatively, the plurality of sequence values is four and the select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1})$   
10  $\text{MOD } 4$  and the step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + S_t) \text{ DIV } 4$ .

Hereby an efficient (1,2,3,4)-step clock controlled m-sequence generation method is provided which is even more  
15 unpredictable.

In general any N-step clock controlled m-sequence generator may be provided according to this invention, where  $N \geq 2$ . Accordingly the select value ( $M_t$ ) may be  
20 calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } N$  and the step control signal ( $S_t$ ) may be calculated as  $S_t = (C_t + S_t) \text{ DIV } N$ .

Hereby an efficient N-step clock controlled m-sequence generation method is provided which an unpredictability  
25 that grows with N.

In one embodiment the plurality of sequence values is generated by a windmill polynomial sequence generator.

30 The present invention also relates to the use of the method and/or electrical device mentioned above in a portable device. In a preferred embodiment the portable device is a mobile telephone.

35 Hereby, efficient and more safe encryption of digitized speech may be obtained.

Additionally, the reduced complexity of the hardware needed saves power which is especially important in e.g. a mobile telephone.

5

The present invention will now be described more fully with reference to the drawings, in which

10 Figure 1 illustrates a functional block diagram of a prior art (1,2)-step clock controlled m-sequence generator;

Figure 2 illustrates a functional block diagram of a  
15 windmill generator;

Figure 3 schematically illustrates a combination of a windmill generator and a Clock and Select system (CS system);

20

Figure 4 shows one realisation of the CS system shown in Figure 3;

Figure 5 shows a preferred realisation of ADD, MOD 2, and  
25 DIV 2 operations in hardware;

Figure 6 shows a generalisation of the bi-rate method described to a quaternary-rate (1,2,3,4)-step clock controlled m-sequence generator;

30

Figure 7 shows a generalized embodiment of a clock controlled m-sequence generator;

Figure 8 shows a flow chart of the method according to  
35 the invention;

Figure 9 shows the preferred embodiment of the invention, which may contain the electrical device and/or use the method according to the present invention;

- 5 Figures 10a and 10b show two exemplary implementations of a system using the method and/or device according to the invention.

Figure 1 illustrates a functional block diagram of a  
 10 prior art (1,2)-step clock controlled m-sequence generator (101). This exemplary generator (101) outputs PN sequence symbols  $Z_t$  (102). The generator (101) has  $L=5$  delay elements (103) each connected to step control means (104) receiving a clock control signal  $C_t$  (105) where  $t$   
 15 denotes the time instants 0, 1, 2,... In this way each element (103) is clock controlled by a sequence  $C = C_0, C_1, C_2, C_3, \dots$ , where each symbol represents the value 1 or 2, i.e.  $C_t \in \{1, 2\}$ .

- 20 As will be seen, every value in the delay element (103) is shifted to the right at each time instant, except the value of the (from left to right) first element (103) which updates to the sum (without a carry) of the values of the second and the fifth delay elements (103) by an  
 25 adding element (106).

If the m-sequence generator (101) steps once every time instant, the generator (101) will produce the simple sequence  $X = X_0, X_1, X_2, X_3, \dots$ . With the shown initial  
 30 values of the delay elements (103) (from left to right 0, 0, 1, 1, 0) the output sequence will be  $X = 1, 1, 0, 0, 0, 1, 1, 1, \dots$ . But if the stepping is controlled by the values of the symbols of  $C$  the following output sequence  $Z = Z_0, Z_1, Z_2, Z_3, \dots$ , will be produced:

35 
$$Z_t = X_{\sigma(t)} \quad t = 0, 1, 2, 3, \dots,$$

where

$$\sigma(t) = \sum_i C_i \quad C_t \in \{1, 2\},$$

and the sum  $\Sigma$  goes from  $i=0$  to  $i=t-1$ . In other words, the next symbol  $Z_j$  is equal to either the next symbol  $X_k$  (if  $C_t = 1$ ) or the next symbol again  $X_{k+1}$  (if  $C_t = 2$ ). As an example, the sequence  $Z_0 = X_0$ ,  $Z_1 = X_2$ ,  $Z_2 = X_4$ ,  $Z_3 = X_6$ ,  $Z_4 = X_7$  will be output if  $C_0 = 2$ ,  $C_1 = 2$ ,  $C_2 = 2$ ,  $C_3 = 1$ .

In this way the unpredictability of the PN sequence  $Z_t$  (102) will be enhanced but creates the need for a clock rate for producing  $X_t$  which is twice as fast as the rate desired for  $Z_t$ , since two symbols of  $X$  must be calculated for each symbol of  $Z$ . The faster clock rate needed results in more circuitry and/or multiple system clocks.

Figure 2 illustrates a functional block diagram of a windmill generator (201). This is a windmill realisation of the m-sequence generator shown in Figure 1. Shown are  $L=5$  delay elements (103) with step control means (104) connected to a next block control signal (202). The windmill generator (201) will output a sequence of the symbols  $Z = Z_0, Z_1, Z_2, Z_3, \dots$  in blocks of two tuples  $(Z_{2t}, Z_{2t+1})$  (205, 206) for  $t = 0, 1, 2, \dots$ . For each time instant a two tuple is generated if the next block control signal (202) is enabled, i.e. true/1. If the next block control signal (202) is disabled, i.e. false/0, the generator repeats the previous block, i.e. does not step to the next block.

The values of the delay elements (103) are shifted from the left to the right at each time instant, except the value of the (from left to right) first element which updates to the sum (without a carry) of the values of itself and the fifth delay elements (103) by an adding element (203), and except the third element which updates to the sum (without a carry) of the values of itself and



the previous/second element (103) by an adding element (204).

As an example, the initial values shown from left to  
5 right (0, 1, 0, 1, 0) will generate the following output  
sequence  $Z_{2t}(205) = 1, 0, 0, 1, 1, 0, 1$  and  $Z_{2t+1}(206) =$   
1, 0, 1, 1, 1, 0, 1 for  $t = 0..6$ , if the next block  
control signal (202) is enabled.

10 In this way the need for extra circuitry and/or an extra  
system clock of higher rate is avoided, since a tuple of  
two values ( $Z_{2t}, Z_{2t+1}$ ) of the PN sequence will be  
generated for each time instant, i.e. at each clock  
cycle.

15

Figure 3 schematically illustrates a combination of a  
windmill generator (201) and a Clock and Select system  
(301). The Clock and Select system (301), denoted CS  
system in the following, will be described in greater  
20 detail for one realisation in connection with Figure 4.  
The windmill generator (201) corresponds to the one shown  
in Figure 2.

The windmill generator (201) generates blocks/tuples of  
25 size  $v$ . In this exemplary embodiment the blocks are of  
the size  $v = 2$ , but blocks of other sizes are also within  
the scope of the present invention, as will be described  
later in connection with Figures 6 and 7.

30 This combination of the windmill generator (201) and the  
CS system (301) will generate a multi-rate clock  
controlled m-sequence.

The output symbols from the windmill generator (201), now  
35 denoted  $X_{2i}$  (302) and  $X_{2i+1}$  (303), are sent to the CS  
system (301). The windmill generator (201) receives a

step control signal  $S_t$  (304) which corresponds to the next block signal (202) in Figure 2.

5 The CS system (301) is responsible for the pacing of the windmill generator (201) by providing the step control signal  $S_t$  (304) and for selecting one of the two output symbols  $X_{2i}$  (302) and  $X_{2i+1}$  (303). The selected symbol is the final output symbol  $Z_t$  (305).

10 The CS system (301) receives a clock control signal  $C_t$  (306) which paces the CS system (301), since one set of symbol  $X_{2i}$  (302) and  $X_{2i+1}$  (303) and thereby one output symbol  $Z_t$  (305) will be generated for each value of the clock control signal  $C_t$  (306). One detailed embodiment of  
15 the CS system (301) will be explained in connection with Figure 4.

In this way, one cipher of the PN sequence will be generated for each clock cycle. The resulting PN sequence  
20 has a high degree of unpredictability since no linear relationship between the output ciphers exists, i.e. either the next symbol or the next symbol again is output. The output is obtained at the same rate as the input clock rate ( $C_t$ ) without the need for multiple  
25 clocks and by very little additional hardware.

Figure 4 shows one realisation of the CS system (301) shown in Figure 3. This realisation of the CS system (301) in combination with the windmill generator (201)  
30 will result in a (1,2)-step clock controlled m-sequence generator.

Shown is selection means (401) adapted to select one of the two symbols  $X_{2i}$  (302) and  $X_{2i+1}$  provided by the  
35 windmill generator (201). The selection is done on the basis of a previously generated select value  $M_{t-1}$  (406)

(generated in the prior time instant as described later). If the previously generated select value  $M_{t-1}$  (406) is false/0 then one symbol from the windmill generator is selected, and if the value  $M_{t-1}$  (406) is true/1 the other  
5 symbol is selected. In the shown example, the symbol  $X_{2i}$  (302) is chosen for  $M_{t-1}$  (406) being false and  $X_{2i+1}$  is chosen for  $M_{t-1}$  (406) being true, but it could also be vice versa. The selected symbol is the final output symbol  $Z_t$  (305).

10

The previously generated select value  $M_{t-1}$  (406) is received from a delay element D (403) which keeps a newly generated select value  $M_t$  (407) for one time instant/clock cycle.

15

The clock control signal value  $C_t$  (306), pacing the CS system, is added by addition means (402) to the previously generated select value  $M_{t-1}$  (406). The sum (408) of  $C_t$  (306) and the previously generated select  
20 value  $M_{t-1}$  (406) can take the values 1,2,3.

From this sum (408) the new select value  $M_t$  (407) is derived by the MOD 2 means (404), i.e.  $M_t$  (407) = ( $C_t$  (306) +  $M_{t-1}$  (406) ) MOD 2, and the new select value  $M_t$   
25 (407) is kept in the delay element D (403), as described above.

The sum (408) is also used to derive the step control signal  $S_t$  (304) which is derived by the DIV 2 means  
30 (405), i.e.  $S_t$  (304) = ( $C_t$  (306) +  $M_{t-1}$  (406) ) DIV 2. The step control signal  $S_t$  (304) is used by the windmill generator (201) to derive the two symbols  $X_{2i}$  (302) and  $X_{2i+1}$ , as described above.

35 In this way, the device shown in Figure 3 is implemented by little use of hardware.

Figure 5 shows a preferred realisation of ADD, MOD 2, and DIV 2 operations in hardware. The combination of ADD, MOD 2, and DIV 2 functionality may advantageously be realised in hardware by a 1 bit half-adder circuit (504).

The clock control signal  $C_t$  (305) is split into two signals,  $C_t^0$  (503) and  $C_t^1$  (502), by a logic circuit (501), preferably according to the following table:

10

$C_t$	$C_t^0$	$C_t^1$
0	1	0
1	0	1

In this way  $C_t^1$  (502) is always equal to  $C_t$  (305) and  $C_t^0$  (503) is always inverted to  $C_t$  (305).

$C_t^0$  (503) is added to the previously generated select value  $M_{t-1}$  (406) by the 1 bit half-adder circuit (504). The result consists of two signals (506, 407) which represents the carry and the sum of the addition, respectively. The sum corresponds to a MOD 2 function since it is performed without a carry. The sum is the select value  $M_t$  (407).

The carry signal (506) corresponds to a DIV 2 function and is used as input together with  $C_t^1$  (502) (equal to  $C_t$  (305)) in an OR gate (505). The result of the OR gate (505) is the step control signal  $S_t$  (304) used to control the windmill generator (201).

This realisation greatly reduces the complexity of the hardware needed to provide a (1,2)-step clock controlled m-sequence generator.

Figure 6 shows a generalisation of the bi-rate method described to a quaternary-rate (1,2,3,4)-step clock controlled m-sequence generator. Shown are a windmill generator (601) and a CS system (602) which has been  
5 generalised from a bi-rate to a quaternary-rate.

The CS system (602) receives the clock control signal value  $C_t$  (603) now  $\in \{1, 2, 3, 4\}$  and the windmill generator outputs four sequence values/symbols  $X_{4i}$  (604),  
10  $X_{4i+1}$  (605),  $X_{4i+2}$  (606),  $X_{4i+3}$  (607) on the basis of the step control signal  $S_t$  (608).

Only one of the four sequence values (604 - 607) is selected as the final output symbol  $Z_t$  (609) of the PN  
15 sequence. The selection of one of the four symbols (604 - 607) in the CS system (602) is still provided on the basis of a previously generated select value  $M_{t-1}$ .

The step control signal  $S_t$  (608) is still provided on the  
20 basis of the clock control signal value  $C_t$  (603) and the previously generated select value  $M_{t-1}$  according to:

$$S_t = (C_t (603) + M_{t-1}) \text{ DIV } 4,$$

25 and the new generated select value  $M_t$  is provided on the basis of the clock control signal value  $C_t$  (603) and the previously generated select value  $M_{t-1}$  according to:

$$M_t = (C_t (603) + M_{t-1}) \text{ MOD } 4.$$

30

In this way a PN sequence with an even larger degree of unpredictability is provided with very little additional hardware.

35 Even PN sequences with a larger rate than four may be implemented, as described in connection with Figure 7,

using the same techniques and giving the same advantages as described above.

Figure 7 shows a generalized embodiment of a clock controlled m-sequence generator. Shown are a windmill generator (701) and a CS system (702) which has been generalised to a  $N$ -rate, where  $N$  is at least 2.

The CS system (702) receives the clock control signal value  $C_t$  (703) now  $\in \{1, \dots, N\}$  and the windmill generator outputs  $N$  sequence values/symbols  $X_{Nt}$  (704),  $X_{Nt+1}$  (705), ...,  $X_{Nt+N-1}$  (706) on the basis of the step control signal  $S_t$  (707).

Only one of the  $N$  sequence values (704 - 706) is selected as the final output symbol  $Z_t$  (709) of the PN sequence. The selection of one of the  $N$  symbols (704 - 706) in the CS system (602) is still provided on the basis of a previously generated select value  $M_{t-1}$ .

The step control signal  $S_t$  (707) may be provided on the basis of the clock control signal value  $C_t$  (703) and the previously generated select value  $M_{t-1}$  according to:

$$S_t = (C_t (703) + M_{t-1}) \text{ DIV } N,$$

and the new generated select value  $M_t$  may be provided on the basis of the clock control signal value  $C_t$  (703) and the previously generated select value  $M_{t-1}$  according to:

$$M_t = (C_t (703) + M_{t-1}) \text{ MOD } N.$$

In this way, a PN sequence with an arbitrary large degree of unpredictability is provided with very little additional hardware.

The degree of unpredictability may be chosen according to a specific need for a given implementation.

5 Figure 8 shows a flow chart of the method according to the invention. The method generates a plurality of PN sequence values/symbols and selects one of these as output.

The method is initialised at step (801).

10

At step (802) a select value  $M_t$  is provided. The select value  $M_t$  may be calculated on the basis of a clock control value/signal  $C_t$  and a previously generated select value  $M_{t-1}$ . The clock signal  $C_t$  may e.g. be provided by an  
15 external control method or hardware circuit. The first time a select value is calculated, the previously generated select value may have the initial value of 0 or 1.

20 Preferably, the select value  $M_t$  is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } 2$  for a plurality of sequence values being equal to two.

Alternatively, the select value  $M_t$  may be calculated as  
25  $M_t = (C_t + M_{t-1}) \text{ MOD } 4$  for a plurality of sequence values being equal to four.

Other functions than MOD and DIV and other values than  $C_t$  and  $M_{t-1}$  may be provided.

30

At step (803) a control signal  $S_t$  is provided. The generated control value  $S_t$  is used to control the generation of sequence values at step (804).

The control signal  $S_t$  may be calculated on the basis of the clock control signal  $C_t$  and the previously generated select value  $M_{t-1}$ .

- 5 Preferably, the control value  $S_t$  is calculated as  $S_t = (C_t + M_{t-1}) \text{ DIV } 2$  for a plurality of sequence values being equal to two.

- 10 Alternatively, the control value  $S_t$  may be calculated as  $S_t = (C_t + M_{t-1}) \text{ DIV } 4$  for a plurality of sequence values being equal to four, but other functions and arguments may be provided.

- 15 The control value  $S_t$  and the select value  $M_t$  are calculated in this way on the basis of the same signals.

- 20 At step (804) a plurality of symbols/sequence values is generated. The generation of values may be done by any kind of sequence generator, e.g. a m-sequence generator, etc., but preferably the sequence generator is a windmill polynomial sequence generator. Alternatively, the generation may be done completely in software by methods corresponding to the mentioned generators.

- 25 The number of generated sequence values may vary according to how safe the method is to be, with a concomitant increase in the computational effort. Preferably, the number of generated values may be two or four, but any other number is just as applicable.

- 30 For two generated values, the next symbol and the next symbol again of the standard m-sequence generator are generated at the same time. For four values, the four next symbols will be generated, etc.

35



Preferably, the generation sequence values are controlled on the basis of the control signal  $S_t$  generated at step (802).

- 5 At step (805) one of the plurality of generated sequence values is selected and output as the next symbol in the output PN sequence. Preferably, the selection is done on the basis of the select value  $M_t$ . This selection of a value between a plurality of uncorrelated sequence values  
10 greatly enhances the unpredictability of the output sequence.

- After execution of step (805) the method loops back to step (802). One loop is executed for each time  
15 step/instance.

In this way, a higher degree of unpredictability is obtained by very little computational effort.

- 20 Figure 9 shows a preferred embodiment of the invention, which may contain the electrical device and/or use the method according to the present invention. Shown is a mobile telephone (901) having display means (904), a keypad (905), an antenna (902), a microphone (906), and a  
25 speaker (903). By including the electrical device and/or the method according to the present invention a more safe and efficient encryption of speech signal is provided, just requiring very little additional hardware and/or additional computational effort.

30

Figures 10a and 10b show two exemplary implementations of a system using the method and/or device according to the invention.

- 35 Figure 10a shows a communications system (1001) comprising a first transmitting/receiving station (1003)

and a second sending/receiving station (1004) where information (1005) may be transmitted. The PN sequences generated by a (1,2)-step clock control m-sequence generator of an embodiment of the present invention may  
5 be used as a sub-component to encrypt information (1005) to be transmitted between the first transmitting/receiving station (1003) and the second transmitting/receiving station (1004).

10 Alternatively, a quaternary-rate (1,2,3,4)-step clock controlled m-sequence generator or other rate generators, as described in connection with Figures 6 and 7, may be provided in the system to improve the unpredictability even further.

15 In this way, safe transmission of information (1005) like data, digitized speech signals, etc. may be achieved by using less hardware, thereby reducing the costs and power consumption.

20 Figure 10b shows a transmitting/receiving station (1003) and a mobile terminal (901) which form a cellular communications system (1002). The information (1005) to be transmitted/received between the mobile terminal (901)  
25 and a network infrastructure (not shown) via the transmitting/receiving station (1003) may be encrypted through the use of a ciphering system that uses PN sequences generated by multi-rate clock controlled m-sequence generators.

30 Alternatively, a quaternary-rate (1,2,3,4)-step clock controlled m-sequence generator or other rate generators, as described in connection with Figures 6 and 7, may be provided in the system to improve the unpredictability  
35 even further.

In this way, safe transmission of information (1005) like data, digitized speech signals, etc. may be achieved by using less hardware, thereby reducing the costs and power consumption.

5

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## P a t e n t   C l a i m s :

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1. An electrical device for generating a multi-rate PN  
5 sequence comprising:

- sequence generation means adapted to output a plurality of sequence values on the basis of a step control signal ( $S_t$ ),

10 c h a r a c t e r i z e d   in that said device further comprises

- selection means adapted to select one of said plurality of sequence values on the basis of a select value ( $M_t$ ), and
- step control means adapted to provide said step control  
15 signal ( $S_t$ ).

2. An electrical device according to claim 1,  
c h a r a c t e r i z e d   in that said select value ( $M_t$ )  
is provided on the basis of a clock control value/signal  
20 ( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

3. An electrical device according to claim 1 or 2,  
c h a r a c t e r i z e d   in that said step control  
signal ( $S_t$ ) is provided on the basis of a clock control  
25 value/signal ( $C_t$ ) and a previously generated select value  
( $M_{t-1}$ ).

4. An electrical device according to claim 1, 2 or 3,  
c h a r a c t e r i z e d   in that  
30 • said plurality of sequence values is two,  
• said select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } 2$ , and  
• said step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + M_{t-1}) \text{ DIV } 2$ .  
35

5. An electrical device according to claim 1, 2 or 3,  
c h a r a c t e r i z e d in that
- said plurality of sequence values is N, where N is at least 3,
- 5   • said select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1}) \text{ MOD } N$ , and
- said step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + S_t) \text{ DIV } N$ .
- 10   6. An electrical device according to any one of the previous claims, c h a r a c t e r i z e d in that said sequence generation means is a windmill polynomial sequence generator.
- 15   7. An electrical device according to claim 6, c h a r a c t e r i z e d in that said sequence generation means comprises:
- a plurality of delay elements (103),
  - step control means (104) receiving a next block control
- 20   signal (202) as input, and
- sum elements (203, 204),
- where each delay element (103) is connected to another and two of them are additionally connected to themselves via a sum element (203, 204).
- 25   8. An electrical device according to any one of the previous claims, c h a r a c t e r i z e d in that said electrical device is used in a portable device.
- 30   9. A device according to claim 8, c h a r a c t e r i z e d in that said portable device is a mobile telephone.
- 35   10. A device according to any one of the previous claims, c h a r a c t e r i z e d in that said electrical device is used in a stationary communication device.

11. A method of generating a multi-rate PN sequence comprising the step of:

- generating a plurality of sequence values on the basis  
5 of a step control signal ( $S_t$ ),  
c h a r a c t e r i z e d in that the method further  
comprises the steps of:
  - providing a select value ( $M_t$ ),
  - providing the step control signal ( $S_t$ ), and
  - 10 • selecting one of said plurality of sequence values on  
the basis of the select value ( $M_t$ ).

12. A method according to claim 11, c h a r a c t e r -  
i z e d in that said select value ( $M_t$ ) is provided on  
15 the basis of a clock control value/signal ( $C_t$ ) and a  
previously generated select value ( $M_{t-1}$ ).

13. A method according to claim 11 or 12, c h a r a c -  
t e r i z e d in that said step control signal ( $S_t$ ) is  
20 provided on the basis of a clock control value/signal  
( $C_t$ ) and a previously generated select value ( $M_{t-1}$ ).

14. A method according to claim 11, 12 or 13,  
c h a r a c t e r i z e d in that  
25 • said plurality of sequence values is two,  
• said select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1})$   
MOD 2, and  
• said step control signal ( $S_t$ ) is calculated as  $S_t = (C_t$   
+  $M_{t-1}) \div 2$ .

30  
15. An method according to claim 11, 12 or 13,  
c h a r a c t e r i z e d in that  
• said plurality of sequence values is N, where N is at  
least 3,  
35 • said select value ( $M_t$ ) is calculated as  $M_t = (C_t + M_{t-1})$   
MOD N, and

- said step control signal ( $S_t$ ) is calculated as  $S_t = (C_t + S_t) \text{ DIV } N$ .

16. A method according to any one of the previous claims,  
5 c h a r a c t e r i z e d in that said plurality of  
sequence values is generated by a windmill polynomial  
sequence generator.

17. A method according to any one of the previous claims,  
10 c h a r a c t e r i z e d in that said method is used in  
a portable device.

18. A method according to claim 17, c h a r a c t e r -  
i z e d in that said method is used in a mobile  
15 telephone.

19. A method according to any one of the previous claims,  
c h a r a c t e r i z e d in that said method is used in  
a stationary communication device.

20



## ABSTRACT

This invention relates to an electrical device for generating a multi-rate pseudo random noise (PN) sequence comprising sequence generation means adapted to output a plurality of sequence values on the basis of a step control signal ( $S_t$ ), said device further comprising selection means adapted to select one of said plurality of sequence values on the basis of a select value ( $M_t$ ), and step control means adapted to provide said step control signal ( $S_t$ ).

Hereby a more cryptographically secure and efficient multi-rate PN sequence is generated.

This invention also relates to a method of generating a multi-rate PN sequence.

Figure 3 should be published.

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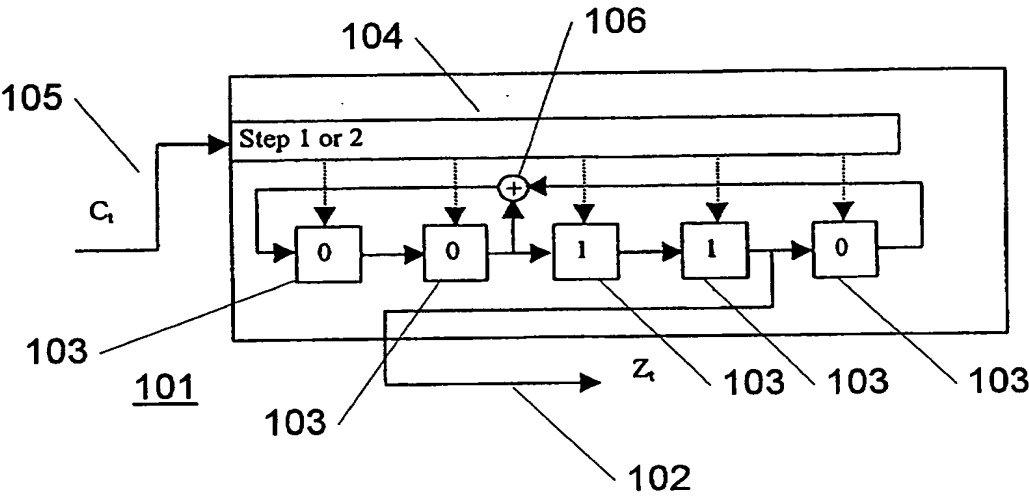


Fig. 1

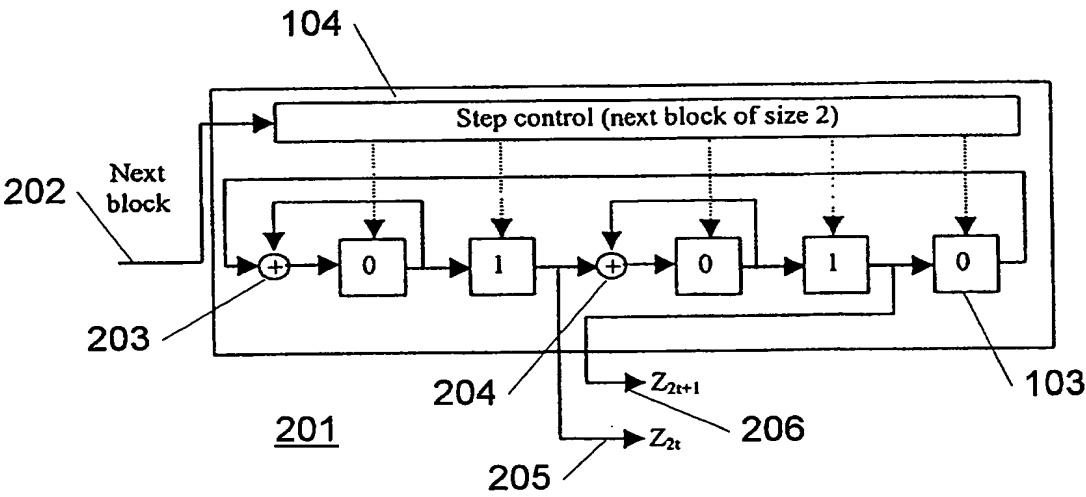


Fig. 2

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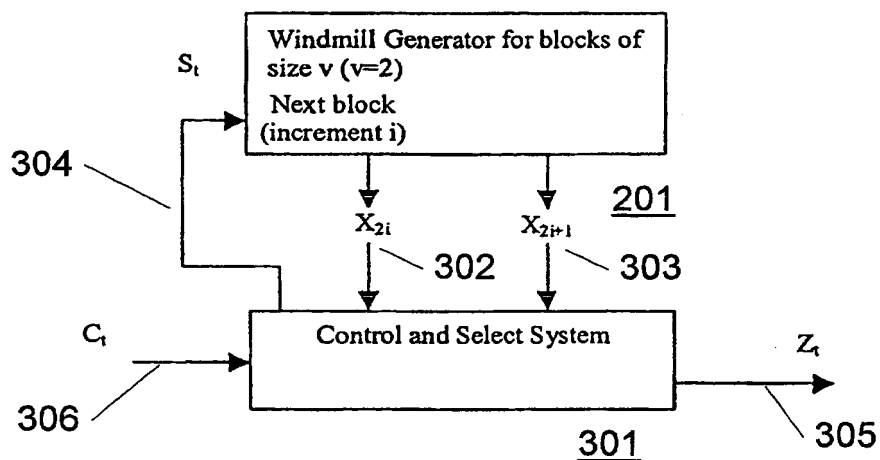


Fig. 3

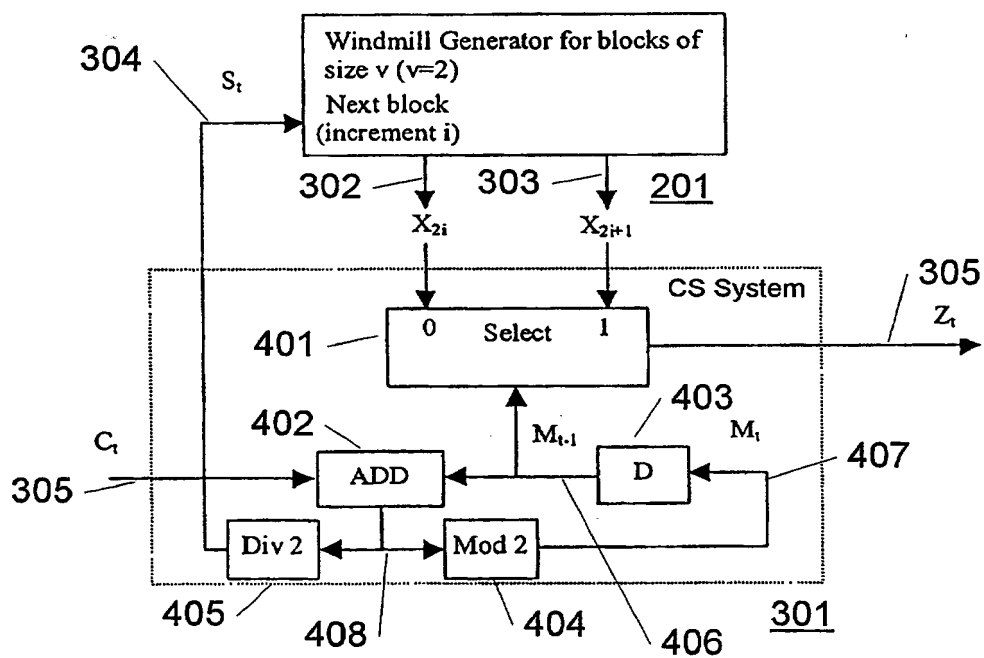


Fig. 4

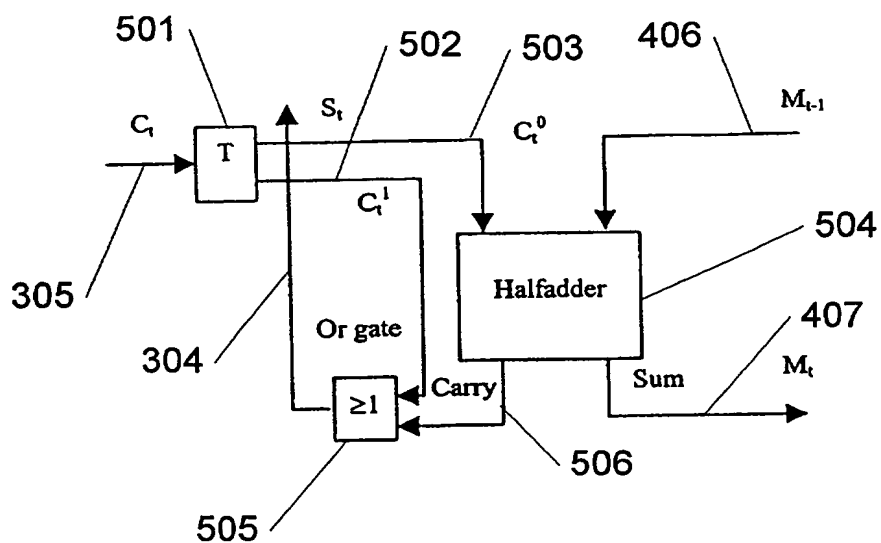


Fig. 5

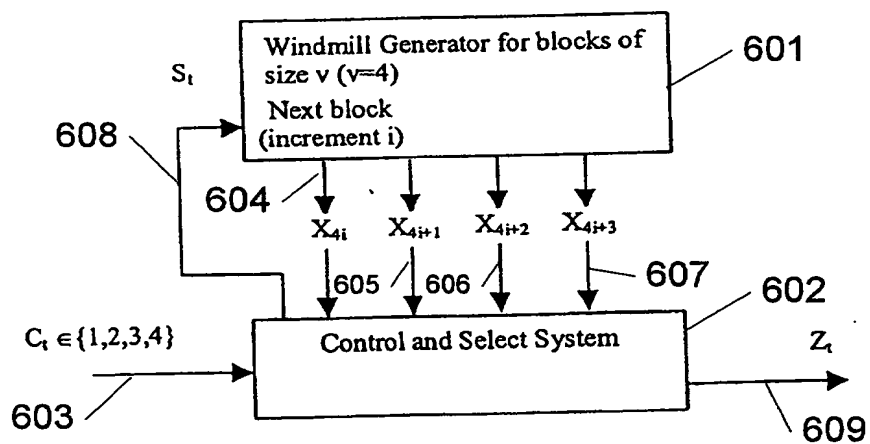


Fig. 6

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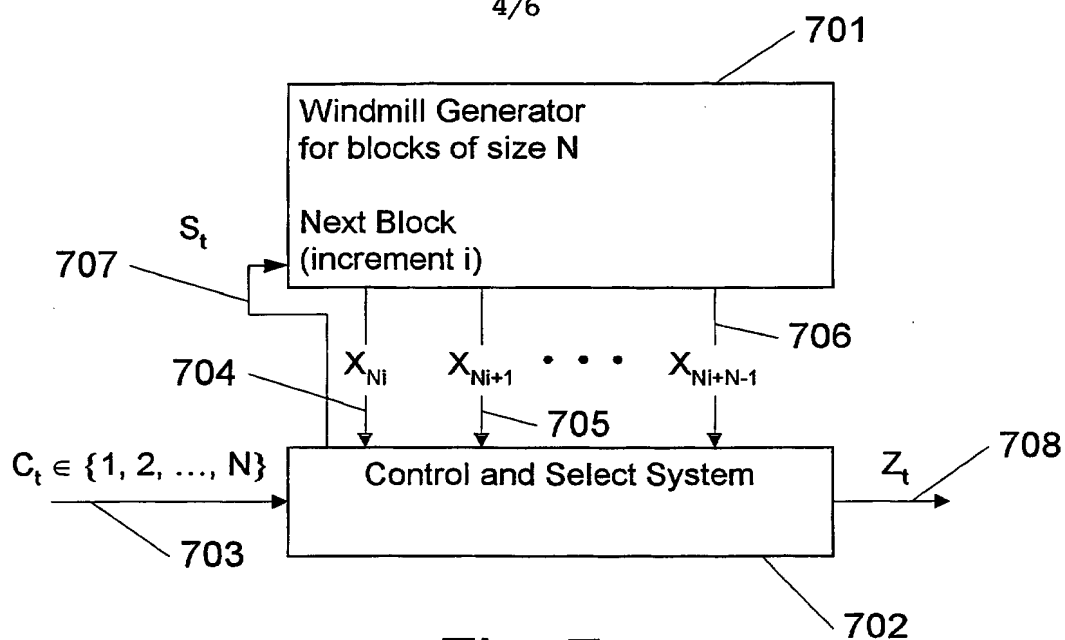


Fig. 7

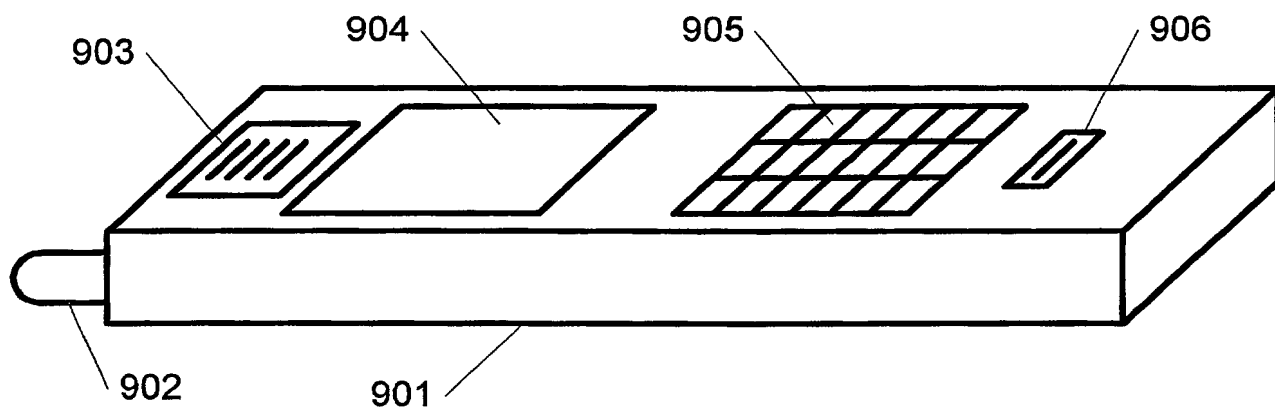


Fig. 9

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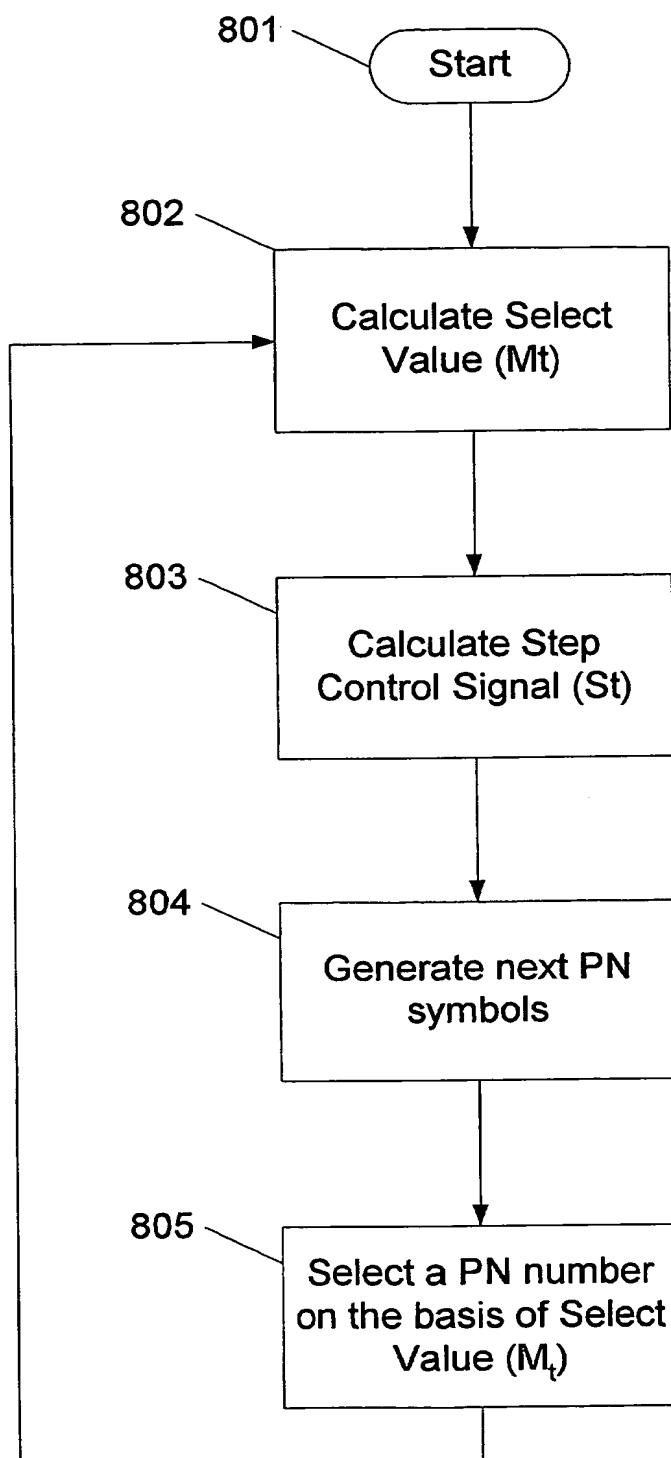


Fig. 8

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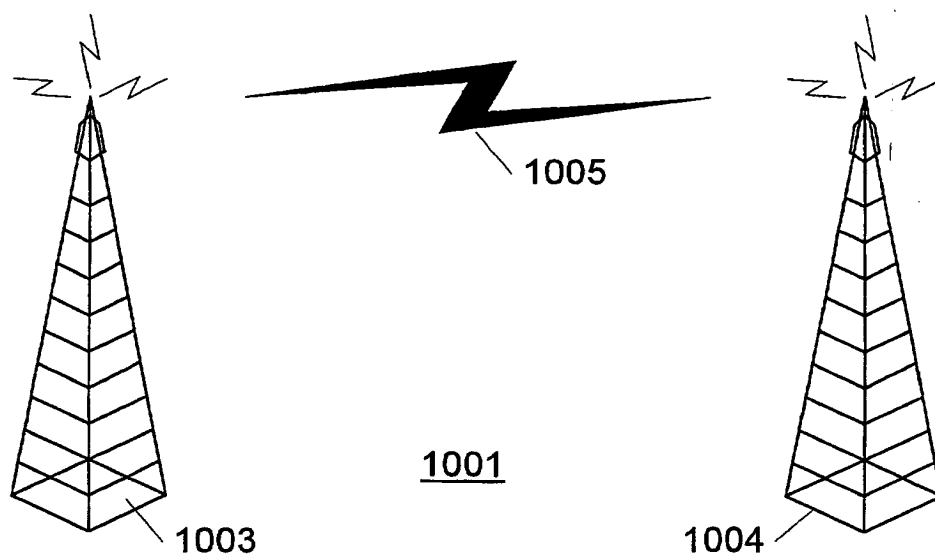


Fig. 10a

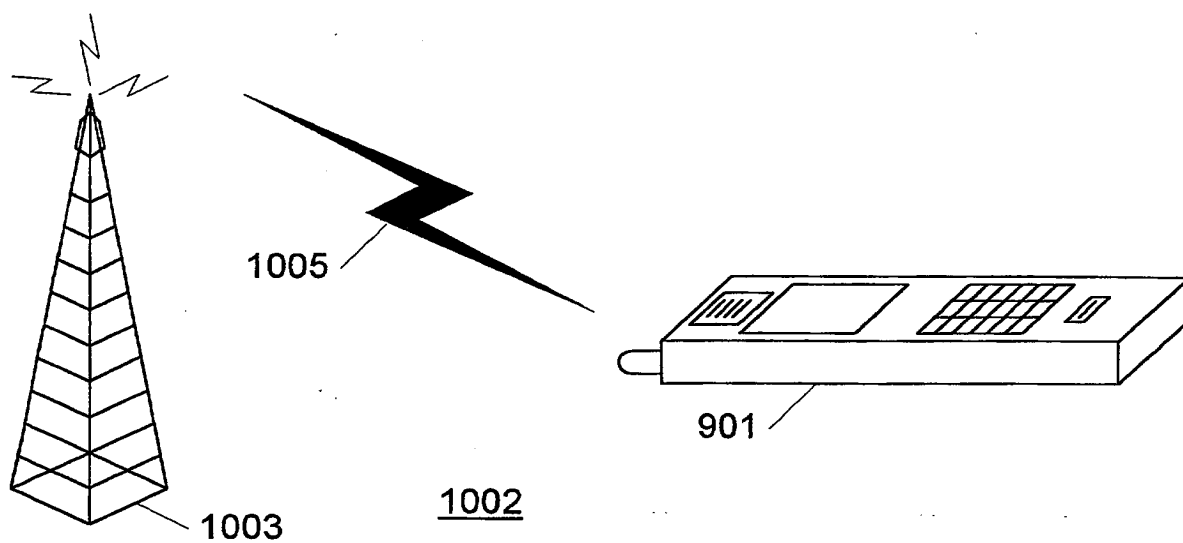


Fig. 10b